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GEOLOGY AND HYDROLOGY IN THE DISPOSAL OF RADIOACTIVE WASTES

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ABSTRACT

The problems of radioactive waste disposal and the talents needed to solve them are varied. Solid, liquid, and gaseous wastes must be handled in different ways. Many of the methods are in the realm of the earth sciences. Ground disposal of solid as well as low- and intermediate-level liquid wastes is an efficient, safe, and economical method when effected under carefully controlled conditions. Geological and hydrological parameters are of utmost importance in this method. Other means of radioactive waste disposal of concern to geologists are being investigated, and more research and development need to be done on these projects.

I. INTRODUCTION

The disposal of radioactive wastes—liquid, solid, and gaseous—presents problems which are of deep concern to the atomic energy industry. A relatively small amount of radioactivity, subjected to various processes including fission, neutron activation, or contamination, can produce a rather overwhelming volume of waste materials which are in various degrees hazardous to mankind. These radioactive wastes cannot be chemically neutralized or treated by methods effective for normal industrial refuse. The natural decay of the contaminants is the only way they are rendered harmless. Decay rates are measured in half lives, which are defined as the time in which half of the nuclei of any given radioactive substance have disintegrated, and these range from less than a millionth of a second to millions of years. The average mixture of high-level fission product waste would require several hundred years before decay had reduced activity levels to a safe plane.

Present disposal methods vary with the nature and actvity levels of the waste materials. Radioactive gases are removed by various processes, they are sometimes tank-stored and more commonly are diffused into the atmosphere via stacks (1). Liquid and solid wastes present greater problems. High-level liquids are almost universally held in tank storage. Solids and low-level and intermediate-level liquids are handled by various methods; however, disposal of these wastes into the ground is universally accepted at present and is being done at most of the major AEC installations such as Oak Ridge, Hanford, and Savannah River, (2) as well as at many smaller sites including Lockheed's Georgia Nuclear Laboratory (3).

Ground disposal of solid and low-and intermediate-level liquid radioactive wastes falls in the realm of the science of geology. The interaction of the wastes with, and movement through, the underlaying soils and rocks are controlling parameters of the efficiency of the method. The geologist must be proficient in other fields as well if he is to deal adequately with the problems involved. He must be well versed in ground water geology and hydrology, as these concern the vehicle for moving the contaminants through the ground; he must know something of chemistry, geochemistry and soil science in order to evaluate decontamination effects by ion-exchange, filtration, and fixation; he should be familiar with health physics to know the relative hazards involved to mankind; he should be something of an ecologist to recognize the effects of radiation upon the living environment; he should be familiar with the basic concepts of sanitary engineering since some of the methods used for industrial wastes have applications in radioactive waste disposal; he should know something of mechanical and chemical engineering in order to understand the entire systems of radioactive waste disposal, including things such as "plumbing" and demineralizers; and finally he should know a little meteorology, physics, bookkeeping, mathematics, and related subjects of benefit to his program. It may be seen, therefore, that to obtain a comprehensive familiarity with all of the aspects involved in the disposal of radioactive wastes, considerable knowledge of subjects generally considered not in the curriculum of geology should be obtained; yet the scope of the problem is basically dependent upon the earth sciences.

II. LIQUID RADIOACTIVE WASTE

1. *Volume of Waste.* The amount of wastes generated has been steadily mounting and with the increasing number of power reactors it is expected that this volume will rise even more rapidly. It has been estimated by Morgan (4) that in 1990 a nuclear power production of 3×10^5 megawatts of heat (which would compose about 10% of the present electrical power production in the U. S.) will create 1.5×10^{11} curies of radioisotopes including 2.6×10^9 curies of Strontium^{90} and 2.3×10^9 curies of Cesium^{137}, the two most hazardous fission products. It has also been estimated by Parker (5) that in the year 2000 there will exist from 2×10^8 to 1×10^9 gallons of high-level waste from nuclear power production, with many times this volume of low- and intermediate-level wastes.

2. *Economics.* No economically feasible method of safe disposal of high-level wastes has been found. Tank storage is considered an interim measure because of the relatively high expense and danger of failure due to corrosion (4). Because of the increasing use of zirconium-clad fuel elements which are dissolved in ammonium fluoride when reprocessed, the quantity of highly corrosive fluoride-bearing wastes which are ill-suited for tank storage (1) will similarly increase.

3. *Contents of Liquid Wastes.* In addition to the fission products occurring in waste solutions, activation products will be formed. These are created by neutron bombardment upon the nuclei of stable iso-

topes. Other deleterious materials in the waste effluents are those found in normal industrial wastes—strong acids and bases, greases and oils, corrosive and noxious chemicals, detergents, and particulate matter, all of which complicate the disposal procedures to an even greater degree. These elements create special difficulties in the method of ground disposal in that they may significantly reduce the percolation rate and ion-exchange capability of soils.

4. *Ground Disposal Methods.* Ground disposal of non-high level liquids is accomplished by pumping the waste into seepage or infiltration pits excavated in the ground. The liquids drain slowly from the pits and enter the water table. During this period various factors operate to reduce activity levels in the waste. Eventually, however, most of the waste will emerge to the surface by wells, springs, or seeps (6). This may be many years from the disposal date. Continuous environmental monitoring must be done to assure that activity levels in uncontrolled areas do not reach a hazardous level. One of the basic precepts of ground disposal of both solid and liquid wastes is the use of areas remote from heavy population centers. This minimizes the danger of radiation uptake by large numbers of humans in event of an accident.

It has been shown that this method of ground disposal of large volumes of low- and intermediate-level liquids is the most economically feasible program used and is efficient and inherently safe (7).

5. *Geology.* Prior to beginning ground disposal, detailed geological and hydrological investigations of the area must be conducted. These have recently been proposed as requirements by the AEC for all future reactor sites (8). These studies would be beneficial in case of an accidental "spill" of radioactive materials to the ground as well as for intentional release of wastes.

The first step in the survey should include detailed geologic mapping of the site. The structure should be determined and cross sections prepared. Mapping should include the entire area of possible contamination by the waste material.

The lithology of the strata must be determined, and petrographic studies should be performed. The porosity and permeability of the soils and substrata will greatly influence the rate and direction of waste movement. Grain size determinations will yield the effective filtration provided for the wastes. The ion-exchange capacity of the soils in seepage pit areas should be determined. This factor presents probably the most important aspect in decontamination of waste solutions. Even a few milliequivalents per 100 grams can effectively retain many curies of exchangeable radioisotopes in relatively small volumes of soil (6). A few radioisotopes such as Ruthenium^{106} resist ion-exchange because of ambivalence, or other properties, and monitoring operations must be geared to watch very closely for members of this group.

Topography influences the shielding of seepage pit sites and controls drainage around them. Care must be taken to avoid surface drainage into pits, for this would add sediment to the bottom and contribute unnecessarily to the volume of liquid to be handled.

6. *Hydrology.* Hydrology is of equal importance in ground disposal of radioactive wastes. A number of test and observation wells is required to determine the hydrological characteristics of a disposal site. Basically tests consist of pumping or bailing a central test well and measuring the drawdown in it and a number of nearby observation wells. Water under pressure may be injected into the test wells as an alternative. Tracers, such as radioisotopes, chemicals, or dyes, may be introduced into the observation wells and the central well sampled regularly and analyzed for the presence of these tracers to indicate the speeds at which they migrate over a known distance and hydraulic gradient.

Similar techniques are applied to test seepage pits prior to their actual use. Water with tracing materials are pumped to the pit, and samples are collected at surrounding monitoring stations. Results may be interpolated to give data on the rate and direction of movement of actual wastes. Also the infiltration rate of the wastes in the pit and an estimate of ground water dilution may be determined.

As wastes leave the pit, they are decontaminated by ion-exchange and filtration. Dilution of the waste solution by the ground water further reduces the activity per unit volume. Should the radioactive solution reach springs and streams, further dilution will occur by these surface waters.

As the pits are used and increasing volumes of liquid are discharged, the level of the water table under the pit in its immediate area will rise, creating a ground water mound. This may cause increased flow in existing springs or emergence of new ones if the water table intersects the surface, and the steepened hydraulic gradients result in more rapid movement, of the waste material, possibly in altered directions. None of the results are beneficial, and the level of the water table must be continuously measured in disposal areas. If a potentially hazardous build-up is observed, corrective steps must be taken, such as reducing the volume of waste released to the pit or even its abandonment.

During the interval radioactive wastes are retained in and shielded by the earth, decay is cotinually at work reducing activity levels. Hydrological conditions may be such that many years elapse before wastes are available for human consumption. Wells located in the path of movement must be periodically checked for increases in radioactivity.

III. SOLID RADIOACTIVE WASTE

1. *Disposal Methods.* Solid radioactive wastes are occasionally stored in vaults, and combustibles are often incinerated. However, burial accounts for the disposal of by far the largest quantity of solid wastes.

Activity levels are reduced by the same factors that act on liquid waste—ion-exchange, filtration, decay, and dilution.

A distinction should be made between contaminated and activated solid wastes. Contamination can be washed or otherwise removed from an article, whereas an activated object emits radioactivity itself and cannot be cleaned. Easily removable activity should be taken off

of objects before burial if they are not to be packaged in corrosion-resistant, leak-proof containers; otherwise the contaminants may be removed by downward percolating precipitation and enter the ground water system. If the level of activity is such that the decontaminating factors at work in the earth cannot reduce levels to a safe plane, hazards can be created. Activated objects, on the other hand, must only be corrosion-resistant, and all of the activity will remain in place with the waste material. It is a wise precaution, however, to place all solid radioactive material in suitable containers prior to burial.

2. *Origin.* The origin of solid radioactive wastes is varied. Items are generated in reactor facilities, radiochemical laboratories, and wherever radioisotopes are used. They may be low-level contaminated laboratory glassware, paper towels, rags, or high-level items such as irradiated test systems, reactor fuel components, or ion-exchange resins.

3. *Geology.* Geological requirements for an area in which to bury such materials are mostly of an engineering nature. A loose overburden and soft bedrock are desirable features for digging operations. The terrain should be level to permit easy transport in the area. The same criteria which apply to liquid waste disposal apply here, because any escaping contamination will be carried by the ground water. Once in this medium, a solid or liquid ancestry becomes immaterial. Therefore such factors as structure, grain size, and ion-exchange capacity are equally important in solid as well as liquid waste disposal.

4. *Hydrology.* The soil overburden should be thick to provide more space for buried objects. The ground water level should be well below the surface, and it should never rise to the level of the buried material. This will prevent a large amount of unnecessary contamination of the water table.

The configuration of ground water in burial areas should be isolated and of limited extent. Thus, contamination reaching the water table should not be able to be transported over long distances and out of the area being monitored. Water table rather than artesian conditions are therefore preferable. This is likewise applicable to liquid radioactive waste disposal.

Springs and swampy areas near burial are obviously detrimental features which should be avoided if possible; if not, they should be carefully monitored, for they provide a means of premature escape of the waste.

IV. MONITORING OPERATIONS

1. *Environmental Sampling.* In any ground disposal operation of radioactive wastes, careful and detailed environmental monitoring studies must be performed. The expected direction of waste movement should be determined and checked very carefully. In addition, all other possible areas must be monitored. Regularly scheduled collections of soil, water, vegetation, and air samples should be performed, and continuous sampling or direct monitoring equipment should be installed at strategic locations.

2. *Maximum Permissible Concentrations.* The Atomic Energy Commission has set forth Maximum Permissible Concentrations (MPCs) of radioisotopes in water and air (9), based on the MPCs as recommended by the National Committee of Radiation Protection (10). Environmental samples collected are prepared and analyzed for gross count or specific critical radionuclides contained in the waste material. The MPCs may not be exceeded in uncontrolled areas without the existance of a possible health hazard; and the organization creating such a hazard may be legally liable for damages, whether real or imaginary.

3. *Ecology.* Studies in radiation ecology such as are being conducted at Lockheed's Georgia Nuclear Laboratories by Emory University (11) are of distinct benefit to a program of ground disposal of radioactive wastes. The effects of radioisotopes on organisms native to the local environment can be determined, and the possibility of the radioactivity entering the human food chain evaluated.

4. *Meteorology.* Meteorological studies are invaluable in determining the direction and rate of movement of gaseous wastes. Evaporation rates and precipitation and temperature records are necessary to adequately evaluate the operational efficiency of seepage pit disposal of liquid wastes.

5. *Records.* Detailed and exact records of the various types of radioactive wastes disposed are necessary for legal protection as well as future calculations. The quantity, activity level, time, and method of disposal used are very important. Results of environmental sample analyses should be filed. This must be a comprehensive and inclusive system of records.

V. OTHER METHODS OF DISPOSAL

So far the discussion has been limited to ground disposal of radioactive wastes by infiltration of liquids and burial of solids. There are other methods of ground disposal of interest to the geologist, most of which are in the research and development stage.

1. *Salt Domes.* The injection of high-level liquid waste into salt domes has been proposed and is presently being investigated in detail by the Waste Disposal Research and Engineering group at Oak Ridge National Laboratory (12). Some of the problems involved concern the plastic flow characteristics of salt, heat generation by radioactive decay, and pressure gradients caused by liquid injection and crustal movement of the earth. Another consideration is the limited extent of salt formations. Often they do not exist at or near sites where disposal of high level liquids is required. The shipment or piping of such material over any appreciable distance generates safety problems and is highly expensive.

2. *Deep Well.* The proposal has been made that deep wells, or abandoned oil wells, be used to receive high-level liquid wastes. The problems of formational clogging, spread of contamination, and heat generation by decay are significant. An overabundance of heat causing steam generation and subsequent excursion of the waste material obviously could be a very dangerous situation. The concept nonethe-

less offers unique possibilities for effective permanent isolation of high-level liquids below the zone of useable ground waters. The oil industry discourages the use of abandoned oil wells on the basis that, as reserves are used up, these abandoned fields may again become valuable.

3. *Abandoned Mines.* Abandoned mines have been suggested as a storage place for solid and liquid wastes. This is feasible for solids; liquids would require a greater degree of impermeability than generally exists. Again, the high cost of transporting wastes to existing abandoned mine locations would often prove prohibitive.

4. *Sea Disposal.* Presently, sea disposal of radioactive wastes is done to a limited extent in the United States. Oceanographers are conducting tests on dispersion of radioactive materials in ocean deeps and off of the continental shelf. The sea will probably prove able to accept relatively large volumes of low- and intermediate-level wastes, but only small volumes of high-level wastes (13).

5. *Solid Fixation.* One of the most promising methods of high-level liquid radioactive waste disposal is that of solid fixation. Certain clays with high ion-exchange capacity, such as illites or montmorillonites, have been tested experimentally for isotope retention. Upon sintering at 800°C or above, the exchanged isotopes are "fixed" on the clays and to various degrees resist leaching (14). The solid material thus formed may be stored or buried without fear of spread of contamination. This method is still too expensive to compete effectively with established methods, but its advantages are such that more research and development work needs to be done.

6. *Other.* There are other methods of disposal of these wastes, but they fall into the realm of the sanitary and chemical engineer rather than the earth scientist. They involve various coagulation, precipitation, and calcination processes, which have been used and are being developed at various facilities.

VI. SUMMARY

The field of radioactive waste disposal is an expanding one and one in which many problems, even basic problems, are yet unsolved. The earth and the sea must receive this material from an expanding nuclear industry, and it is a challenge to earth scientists and others to find acceptable economical, and safe methods for the disposal of radioactive wastes.

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THE DAIRY INDUSTRY OF THE UNITED STATES AS INFLUENCED BY BULK HANDLING OF MILK ON DAIRY FARMS

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Handling milk in bulk tanks on dairy farms of the United States has been one of the most revolutionary steps since the development of the process of pasteurization. This development is rapidly changing the entire dairy industry of the United States as well as other nearby countries.

From available evidence this development had its real beginning in California in the late 1930's. However, it was not until the mid-1940's that any appreciable expansion of this practice was noted. Again it was in California and also on the larger dairy farms in Florida that the widespread use of farm tanks began to be practiced. This development was studied with much interest by the dairy industry and particularly by equipment manufacturers. By the late 1940's and early 1950's several manufacturers had farm tanks on the market and interest in their use was spreading rapidly throughout the United States.

Perhaps it is fortunate that the use of tanks for storage of milk on dairy farms did not spread more rapidly during the early years of this development. This provided ample time for study of the practice and allowed equipment manufacturers an opportunity to fabricate tanks specifically designed for farm use. Refrigeration units for use in these tanks were vastly improved, and farm to market highways were designed and built that would accommodate large transport trucks for hauling the milk.

In June, 1953, a survey by the U. S. Department of Agriculture revealed 3,150 farm tanks in use in the U. S. By January, 1956, this figure had increased to approximately 30,000 and in January, 1958, more than 91,000 farm tanks were in use. By this time it is likely that more than 135,000 tanks are in use on dairy farms of the United States. Here in Georgia the development has been equally well received. For example, of about 1,000 farms which supply milk for the Atlanta market, about 750 are equipped with bulk tanks. In some Georgia markets 100% of the milk supply is from farms equipped in this manner.

Following is a brief explanation of how the bulk tank system operates:

Instead of using the conventional milk cans, the milk is stored in a refrigerated tank. It is transported to the processing plant in an insulated tank mounted on a truck. The truck follows prescribed farm routes and pumps the milk from the farm storage tank through a sanitary hose into the insulated transport tank. Many of the modern dairy farms have completely closed milking systems whereby the milk passes from milking machines through a glass or stainless steel pipeline to the storage tank. Where this system is not in use the

milk is poured directly into the tank from the stainless steel milking pail.

As the milk from each cow enters the tank it is cooled rapidly to 40 degrees F or lower. The tanks are individually calibrated by local regulatory officials at the time of installation. In some areas milk is picked up at the farm on alternate days. Such an arrangement requires a tank large enough for the total milk produced during two days. As a precaution, however, enough extra tank capacity for at least one additional milking is recommended. The same is true where milk is picked up daily.

When the truck arrives at the farm, the driver measures the milk in the tank with a calibrated stainless steel rod, thoroughly mixes it, takes a sample for butterfat test, records the temperature of the milk, and makes a careful organoleptic appraisal of the flavor and aroma. If the milk is of good quality, he pumps it from the farm tank into the transport, and finally, flushes out the farm tank with clean warm water. Drivers are also being licensed by health departments to collect samples for bacteria counts.

Samples of milk for bacteria counts are taken at periodic intervals varying from semi-weekly to semi-monthly. Butterfat samples are taken each time the milk is picked up and may be tested in the laboratory daily or a composite sample may be tested at the end of each week or each two weeks.

Obviously, such a system is very much in contrast to that of handling milk in cans, a system which is common throughout the world.

It would be well to consider briefly the reasons for this phenomenal development and the possible influence it may have on the dairy industry of the United States in the future. It is evident that this new system has many advantages for both the farmer and the processor. From the viewpoint of the farmer the greatest advantage is the elimination of the laborious task of lifting heavy containers of milk. Especially is this true in areas where the tank is used in connection with the pipeline milker system. Not only is the task of milking made easier, but the time required has been reduced, thereby making possible better utilization of labor. The time required to clean the tank, for example, is only a small percentage of the time required to clean the milk cans. With the constant improvement of the CIP system of cleaning tanks and milking equipment, the time required for this task will be reduced further.

In some instances the farmer receives a premium price for his milk as a result of the change to the bulk tank. This may amount to as much as 15 cents per hundred pounds of milk. In addition a farmer can usually expect a substantial saving in hauling charges, especially when milk is picked up on alternate days. This saving may amount to as much as 15 cents per hundred pounds.

Obviously, some savings may be expected from the amount of milk sticking to the side of the tank as compared to the amount remaining in the cans, especially if the cans were not completely drained. Since the milk is paid for on the basis of the measurement in the farmer's

tank, the truck operator makes every effort to thoroughly drain the tank.

Since the milk is thoroughly and completely mixed before the butterfat sample is taken, the farmer is assured that an accurate sample is obtained.

Probably of greatest importance, however, is the improvement in quality of the milk. No longer can the farmer using a bulk tank afford to run any risk as to the flavor and sanitary quality of his milk. He must know before the cows are milked that the milk is going to be of acceptable quality. This is especially true when the pipeline milking system is used. Milk of objectionable quality from even one or two cows can ruin an entire tank of milk—possibly as many as four milkings. Consequently, the farmer very quickly becomes more quality conscious than ever before. Bacteria counts, likewise, are much lower in milk handled in bulk tanks. The reason for this is that cleaning and sanitizing the stainless steel surfaces of the tank is more effectively accomplished than with the individual milk cans. Furthermore, the cooling of the milk in the tank is more rapid, thus reducing the opportunity for bacterial growth.

Likewise, there is a material saving for the processor since he eliminates the entire operation of receiving milk in cans. He has savings in labor, space and materials. In addition, since the burden of responsibility for accepting only high quality milk from the farmer rests upon the operator of the truck, the plant operator is assured of a product of good quality.

The farm tank development, however, has presented some very real problems to the dairy industry of the United States. One of the major problems is the cost of the new equipment. Obviously, the bulk tank is better adapted to the farmer producing several hundred gallons of milk daily. Most of the dairy farms of the United States, however, are relatively small. Therefore, when a processing plant decides to purchase milk only from farms equipped with bulk tanks, some farmers supplying the plant with milk are faced with a decision of great significance.

Installation of a farm tank requires an investment ranging from as low as $1,500 for a 100-gallon tank to as much as $5,000 or more for a 1,000-gallon tank. A small farmer may have difficulty in justifying the added investment on the basis of his present volume of production. Therefore, he must add more cows and produce more milk. These additional cows will increase his investment still further and may complicate his feed production program. If he decides against changing to the bulk tank program, he must either find a market for his milk in cans, or discontinue producing milk. Surveys indicate that some farmers discontinue production when faced with this situation. However, those who install bulk tanks almost always increase their production.

Farm bulk tanks must have sufficient refrigeration capacity to reduce the temperature of the milk to 40 degrees F or lower within one hour after milking is completed. Likewise, it must be sufficient

to maintain a temperature of 50 degrees F or lower in the milk within the tank during subsequent milkings.

Farm bulk tanks are available in a variety of sizes, ranging generally from 100 gallons to as much as 1,000 gallons. Farms requiring tanks with a larger capacity than 1,000 gallons usually install the same type tank as is generally used in processing plants for storage of milk.

As the trend for increasing use of farm bulk tanks for storage of milk continues, one may well raise the question as to the influence this may have on the future of the dairy industry in this area. Certainly, dairy farms using the bulk tank will tend to become larger and more specialized. This is very evident from even the short time they have been in use. With more than 50 percent of all milk being sold for fluid consumption already produced under this system, it is quite reasonable to assume that within a few years virtually all Grade A milk will be produced on farms equipped with bulk tanks.

Farmers not willing to install such equipment or who are not in position to increase their investment with a reasonable profit may find it necessary to sell their milk to plants for manufacturing cheese or other dairy products. However, some manufacturing type milk, even now, is being produced on farms equipped with farm bulk tanks. It is very likely that with the large farms producing even this type milk, the bulk tank will become standard equipment.

In any event, the use of the farm bulk tank is destined to bring to the consuming public a product of higher quality. Likewise, it will improve the life of the dairy farmer by removing one of the most laborious tasks associated with the dairy industry, namely lifting cans of milk into and out of the refrigerated box. It will bring him economies in labor, hauling, electricity, and will increase his operating efficiency. For the dairy plant operator, this system, likewise, will bring economies as well as an improved quality of raw milk.

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THE CUNA INDIAN GARDEN OF EDEN

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In a group of eighteen articles published in this Bulletin and four in the Journal of the Tennessee Academy of Science I have described many phases of the primitive Cuna Indian culture of San Blas, Panama, that I have studied during ten years. One of the most outstanding facts about Cuna traditions is their identifications with a whole series of neolithic religious stories of worldwide distribution. Among these stories there were a number of surprises.

The first surprise of this study was the discovery of what is apparently the original meaning of the Garden of Eden Story, namely, an allegorical account of the Earthmother's parturition when she gave birth to the first plants, animals and man. A second surprise was the finding that the oceans of the world were formed from the salty amniotic fluid of the Earthmother, expelled when she gave birth. A third surprise was to learn that in the original story of the Great Flood the inundation was caused by the Bursting of the Waters of the Earthmother in the parturition scene. A fourth surprise was the confirmation of a hunch that the world famous Tree of Life represents symbolically the umbilical cord and foetal membranes of the Earthmother. A fifth surprise was to realize that all the religious stories are parables intended to deceive the uninitiated. The final surprise was to verify the indication that the swastika is the Tree of Life turning in the Water of Life, as seen from above.

Chief Ikwaniktipippi's Water Color Picture of the "Garden of Eden" Scene in the Council Hall of Ailgandi.

These findings have been discussed in detail in the articles mentioned, and some of them in *Land of the Moon-children*. The neolithic, religious stories of the Cunas have been treated comparatively in a book manuscript entitled *Secrets of the Cuna Earthmother*.

Because of reluctance on the part of Cuna medicine priests to communicate the true meanings of their religious parables I was not certain of all the details of the Garden of Eden scene for seven years, having to pry them out slowly bit by bit especially from Chief Ikwaniktipippi of Ailigandi and Chief Olotapillikinya of Ustuppo who know the traditions best.

Great was my astonishment, therefore, when I entered the Congress Hall of Ailigandi in June, 1959, and found a large, framed, watercolor picture of the Garden of Eden scene roped to one of the cross beams. It was the work of Chief Ikwaniktipiippi and confirms completely my previous interpretations. The photo is explained in the labeled sketch.

Puksu (1) the Morning Star (brother to Olowaipippilele the Sun-god) slays the phallic Serpent at lower left. He also dispatched the Placental Monster and the Great Toad in fierce combats.

Olowaipippilele (2), with a stone axe, severs the Paluwalla Tree of Life (3) which is hollow, allowing the salty River of Life (4) to flow out at the lower right to form the Oceans of the World.

Sketch of Ikwaniktipippi's picture of the Cuna Indian "Garden of Eden" scene. The elements of the picture are numbered in order to identify (1) Puksu and Serpent, (2) Olowaipippilele, (3) Paluwalla Tree of Life, (4) River of Life, (5) Earthmother's Vulva, (6) whale, (7) lizard, (8) eagle, (9) sulu monkey, (10) tapir, (11) fish, (12) Olokukurtilisop, (13) Olokukurtilisop's Butterfly, (14) Earthmother's Table, (15) Cloth on Table, (16) Akwa Nusa stone, (17) a mother, (18) mother's newborn child, (19) package containing placenta, (20) coconut tree, (21) coconut.

The umbilical cord and membrane Tree of Life (Sapi purpa neik perkueti) rises from the Earthmother's Vulva (5). Fastened by their umbilical cords to the Tree of Life are a whale (6), a lizard (7), an eagle (8), a sulu monkey (9), a tapir (10), and a fish (11) as representative animals.

Behind the Tree of Life are the head and shoulders of Olokukurtilisop (12) the Great Earthmother identified by her giant, luminescent, blue Butterfly (13). Between the Earthmother and the Tree of Life is the Earthmother's Table (14) representing her vaginal lips. The Cloth (15) upon the Table represents a menstruation prior to conception. To the left of the Table will be seen what may be a most sacred Akwa Nusa (16) stone representing a menstrual clot of the Earthmother.

At the upper left is a woman (17) who has just borne a child (18) after the pattern set by the Great Earthmother when she bore her children. To the hammock string is hung a banana leaf bundle (19) containing the placenta of the child.

To the extreme right is a coconut tree (20) under which the placenta will be buried. The coconut tree here represents the Tree of Life symbolically and will become the permanent possession of the child. Near the base of the coconut tree is half of a coconut (21) representing the womb and indicating that parturition has taken place.

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THE PIRI REIS MAP AND CULTURAL DIFFUSION

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Piri Reis was a distinguished admiral in the Turkish Navy and a cartographer of great reputation. Admiral Reis had as a slave one of the pilots of Columbus, a veteran of three of the latter's four voyages of discovery in America. This slave had with him a very ancient map belonging to Columbus showing the eastern coast of America from Yucatan and Guatemala around South America and even including the Palmer Peninsula in Antarctica.

Using this map and nine Greek maps from the time of Alexander the Great, Admiral Piri Reis constructed a Map of the World in 1513 A.D. Thus, the Piri Reis Maps of the world were based on data collected more than 2,000 years before the time of Columbus. The Piri Reis maps were long lost, but about 1953 a Turkish Naval Officer gave a copy of the famous Piri Reis map of Central and South America plus Antarctica and West Africa to the Chief Engineer of the United States Hydrographic Office. The original charts from which it was derived may have been of Greek or Phoenician origin. No other of the Piri Reis maps have been found to date.

An ancient chart of Antarctica, as well as ancient maps of the Mediterranean region, Iceland, Greenland, Northern Russia and Western Siberia, have been found to be based on the same unique method of reference points which may have been the forerunnner of Mercator's projection. On the ancient maps of Greenland and Antarctica are detailed shore lines for thousands of years hidden by massive glaciers that today spread far out over the water in glacial shelves. The shore lines beneath the glaciers have been determined recently by seismographic soundings and are found to correspond accurately with the shore lines on the ancient Columbus-Piri Reis Map of Antarctica and the ancient map of Greenland. The Map of Antarctica is particularly interesting because the remarkably accurate shore lines were charted at least 2,000 years ago before the glacier formed. This was also true for the Greenland map. One old map of North America of Scandanavian provenance shows a glacier that existed 15,000 years ago but has since disappeared. This map is thought to be 5,000 years old. All these ancient maps are in the Library of Congress.

Old iron furnaces in Ohio and Virginia have been excavated, and it was discovered that the iron had been produced by the powdered method of metallurgy employed anciently in Europe and Egypt at a time contemporary with the original production of the ancient maps which must have been prepared by professional groups of ancient experts adept in determining positions by means of the sun and stars and skilled in the methods required for topographical surveying.

These facts are contained in "Lost America," 1956, Overlook Company, Box 6037, Washington 5, D. C. The author is Arlington Mallery.

Lost America is of particular interest to those who believe, as I do, that there were many trade contacts between America and both Europe and Asia over long periods prior to the time of Columbus which permitted a world-wide cultural diffusion at least as far back as the bronze age of Egypt and Mesopotamia, if not during the time of neolithic traders. Such contacts are demanded by my studies of the Cuna Indian culture when compared with other primitive cultures of the world.

PAPERS PRESENTED AT THE

THIRTY-SIXTH ANNUAL MEETING

OF

THE GEORGIA ACADEMY OF SCIENCE
MERCER UNIVERSITY

AS PART OF A SYMPOSIUM ENTITLED:

"THE IMPACT OF DARWIN'S IDEAS"

One Hundred Years of Darwinism, 1859-1959
W. B. Baker

Darwin's Anatomy of Human Nature
Alfred G. Smith

Darwin's Effect on Paleontology
H. R. Cramer

Cytogenetics and Evolution
R. H. Fetner

ONE HUNDRED YEARS OF DARWINISM—1859-1959

W. B. Baker
Emory University

I. *Introduction*

On December 27, 1831, a voyage was begun on the brig, H.M.S. Beagle, which was to result in the discovery of material of far-reaching significance in all areas of man's intellectual activities, but particularly in the field of science. Two men were to play the leading roles on the voyage. One was Captain Robert Fritz-Roy, 26 years of age and a deeply religious man, who had little patience with the new-fangled geology which taught that the earth was very much older than the 17th century theology indicated. The other was Charles Darwin, only 22 years old and as yet unsettled as to a career, but already having demonstrated an independence of thought and a breadth of interest in natural history. Fitz-Roy, who had made many voyages over the world, wanted a naturalist to accompany him on a survey of the South American coastline. Darwin was offered the place but having had no experience with sea voyages, was somewhat hesitant. Fitz-Roy painted a glowing picture of the experiences they might hope to have and insisted that the tales of rough seas and stormy weather were exaggerated. He offered the use of his large library, his instruments, guns and equipment for collecting and traveling. He also suggested that if Darwin did not like the trip he could return at any time to England or be left off at some nice country to do as he pleased. Darwin's father objected to the proposed trip and said, "If you can find any man of common sense who advises you to go I will give my consent." His Uncle Josiah Wedgewood II convinced the father that the trip was a good idea. Darwin's friends, Sedgewick and Henslow, urged him to go, so he accepted.

> "So began the journey in which a great mind untouched by an old-fashioned classical education was to feed its hunger upon rocks and broken bits of bone at the world's end, and eventually was to shape from such diverse things as bird beaks and the fused wing-cases of island beetles a theory that would shape the foundations of scientific thought in all the countries of the earth."
>
> L. C. Eisley, Sci. Amer. Vol. 194, No. 2, Feb. 1956. Page 62.

The expedition returned to England in 1836.

II. *Darwin the Man*

Darwin was born in 1809, the same year that marks the birth of Abraham Lincoln. It is interesting to note that while Lincoln did much to free men's bodies Darwin did much to free man's minds. Had Darwin known Lincoln the two men would have had much in common since Darwin records his revulsion to the institution of slavery as he saw it practiced in various parts of the world during his travels.

Darwin was the son of well to do parents and could have grown up to be a "gentleman idler" had he not come into contact with some great men during his various experiences in schools—men such as Sedgwick, Lyell, Hooker, and Henslow.

The youth did not know what he was going to do. It is said that he was a difficult child, hard to arouse, slow to learn, seldom eager, a self-centered day dreamer. He was weak at spelling and bad at languages, somewhat more timid and a bit more gullible than most of his school-mates; a thoroughly commonplace school boy. He had no clearly defined bent. We might mention that from what we know of the boy we would certainly eliminate him from entrance to college or graduate school if he were applying to any of our institutions today.

He was sent to Edinburgh in 1825 at the age of 16, to study medicine. His father, Dr. Robert Darwin, a prominent physician in Shrewsbury, was determined his son should become a doctor. However, when it was reported to him that Charles expressed disgust at dissections and horror at operations, and that he consistently dozed during lectures and wasted his time in studying the life in pools and puddles and in consorting with the oystermen, he took him out of medicine and sent him to Christ's College, Cambridge, to train for the ministry. Here he continued to loaf and spend much of his time reading books on natural history and adventure, in attending lectures by Henslow, collecting insects, rocks and fossils. He graduated, however, and spent the first vacation in a collecting trip with Sedgwick the geologist. At the conclusion of this trip he was nominated by George Peacock to become naturalist on the H.M.S. Beagle, for a projected trip around the world. Henslow had been offered the place but turned it down and endorsed Darwin for the place. He was 22 years of age when he began the voyage and after five years of travel returned to England much matured, with notebooks filled with records of his observations and impressions, with boxes and cases of specimens, and with a head full of ideas. In the seclusion of his country home he began to correlate the mass of data and material into a journal of his trip on the Beagle and several short notes on specific areas. He showed no desire, however, to rush into print with short abstracts nor incomplete papers which did not represent careful analysis and evaluation of all available data. Fortunately he was not faced with the necessity of presenting an impressive list of publication titles in order to apply for a position. He has been criticized by some for his deliberateness in getting his material ready for publications, but perhaps it was this attribute which gave his final summary of ideas such significance.

Darwin attributed his success to four characteristics:

1. The love of science
2. Unbounded patience in long reflecting over any subject
3. Industry in observing and collecting facts
4. A fair share of invention as well as of common sense

Many have criticized Darwin for having lost his appreciation of beauty, of ideals and of the higher things of life because of his ideas about the origin and development of species through the operation

of natural forces. These critics have too frequently spoken without any knowledge of the works of Darwin or of the high regard in which he was held by those who knew him.

One has only to read his books, particularly the Journal of his Voyage on the Beagle or his book on the Descent of Man to find that Darwin retained his humility and faith in the power and work of a Supreme Being during his entire life. A few quotations from some of his books gives an insight to the real character of the man:

> "I am strongly induced to believe that as in music, the person who understands every note, will, if he also possesses a proper taste, more thoroughly enjoy the whole, so he who examines each part of a fine view, may also thoroughly comprehend the full and combined effect."
>
> Journal of Researches, p. 502

> "Among the many scenes which are deeply impressed on my mind, none exceeds in sublimity the primeval forests undefaced by the hand of man; whether those of Brazil, where the powers of life are predominant, or those of Tierra del Fuego, where death and decay prevail. Both are temples filled with various productions of the God of Nature; no one can stand in these solitudes unmoved, and not feel there is more in man than the mere breath in his body."
>
> Journal of Researches, p. 503

> "Music arouses in us various emotions, but not the terrible ones of horror, fear, rages, etc. It awakens the gentler feelings of tenderness and love, which readily pass into devotion."
>
> Descent of Man, p. 583

> "The feeling of religious devotion is a highly complex one, consisting of love, complete submission to an exalted and mysterious superior, a strong sense of dependence, fear, reverence, gratitude, hope for the future, and perhaps other elements."
>
> Descent of Man, p. 97

> " . . . . but ignorance more frequently begs confidence than does knowledge; it is those who know little, and not those who know much, who so positively assert that this or that problem will never be solved by scienee."
>
> Descent of Man, p. 2

III. *Publication of the Origin of Species*

After returning to England in 1836 Darwin began to write a series of notes on the "transmutation of species" and to formulate certain basic ideas which were to be elaborated later. Among these were:

1. The mass of facts suggests descent with modification.
2. There seems to be a common ancestry of all living things.
3. Natural selection determines which ones will survive.

In 1838 he read the book by Malthus on population which suggested that increase in population is in geometric ratios while food supplies increase arithmetically. This suggested to Darwin the idea of struggle for existence, and if variations were present, the fittest of the population would survive.

He did the first of his studies and writings in London but in 1842, after his marriage to his cousin, Emma Wedgwood, granddaughter of the founder of the famous pottery works, he moved to a country home in the small village of Kent.

In 1842 he wrote a pencilled abstract of the theory of evolution, consisting of 35 pages. This was not published but was found under the stairs of his home some 50 years later.

In 1844 he elaborated on the original abstract and wrote some 230 pages giving many additional facts which had led him to his conclusions. This too was not published but was discussed with his friends Lyell, Hooker, and Asa Gray. None of these men were very enthusiastic and expressed doubts as to the validity of the conclusions. This reaction caused Darwin himself to doubt but increased his determination to restudy his materials and his notes to support or refute the original conclusions. The more he persevered the more convinced he became of the truth of the basic theory.

In 1845 he published the second edition of his Journal of Researches dedicated to Charles Lyell, "As acknowledgement that the chief part of whatever scientific merit this journal and the other works of the author may possess, has been derived from studying the well-known and admirable Principles of Geology."

In 1857 he wrote a letter to Asa Gray explaining in detail his ideas and conclusions. Gray and other friends in England insisted that the material be published but in 1858 Darwin received a letter from Wallace outlining an idea of "the origin of species and the part played by natural selection." The outline was so nearly a duplicate of his own that Darwin was much disturbed and perplexed about what to do with his own manuscript. Ten days later his crippled son died, which further agitated his troubled mind.

Hooker and Lyell suggested a joint paper be presented to the Linnaean Society on July 1, 1858. Darwin consented but said—

"I would far rather burn my whole book than that he or any other man should think that I had behaved in a paltry spirit." Wallace in turn showed a magnanimous spirit when he gave the name "Darwinism" to the theory that both had developed. He minimized his own part in the elaboration of the theory as "one week to 20 years."

The book, *Origin of Species*, was published on November 24, 1859, the entire edition of 1250 copies being sold out the first day.

The three basic concepts of greatest meaning today were the same as Darwin had outlined in 1836, over 20 years earlier. These were:

1. A web of life—a common ancestry of all living things.
2. Descent with modification.
3. Natural selection.

In elaboration of these ideas several suggestions were made in the form of explanations of the processes. Particularly significant were (1) the theory of pangenesis, (2) the direct effect of environment in producing changes. Though he did not claim to believe in Lamarckian ideas of use and disuse, much of his evidence for this theory showed the influence of Lamarck.

IV. *The Reception of the Book*

The intellectual climate of England at the time was predominantly conservative. Religious dogmas greatly influenced scientific thinking. The 17th Century ideas of creation 4004 B.C. were accepted as true. Agassiz in America, Owen in England, and Cuvier in France had explained fossils, which to many furnished evidence for the new theory, as separate creations becoming extinct through accident.

The English have always been wary of acceptance of new ideas, hence considerable opposition to the idea of evolution was to be expected. Many accepted the new ideas enthusiastically as evidenced by separate statements:

Huxley said after reading the book—"How extremely stupid not to have thought of that."

Hooker accepted wholeheartedly.

Lyell—enthusiastic.

Sedgwick "read with more pain than pleasure" but later became enthusiastic.

Hewett Watson, a botanist, wrote to Darwin regarding the theory: "It has the characteristics of all great natural truths, clarifying what was obscure, simplifying what was intridate, adding greatly to previous knowledge. You are the greatest revolutionist in natural history in this century, if not of all centuries."

In 1860 a debate on the theory was held at Oxford, with Huxley defending and Bishop Wilberforce attacking. Wilberforce had not read the book but had been coached as to its contents and set out to "smash Darwin." Huxley, known as Darwin's bulldog, smashed Wilberforce. Since 1860 many debates and controversies have arisen because of the thories suggested by Darwin. Much abuse has been directed toward Darwin as well as to those who have accepted the general idea presented, even though not the details. Much of this abuse directed toward Huxley, Darwin, and others, has been by persons who have no first hand knowledge of the work nor of the evidence supporting the idea and conclusions presented.

V. *Misunderstanding and Misinterpretation of Meaning of Evolution*

This misunderstanding has arisen in the public mind for several reasons:

1. Because of the debates among biologists as to the manner in which evolution has occurred and the efficient causes which have brought it about.

2. Because of the ambiguous way in which the term Darwinism is often used. *Darwinism* is not a synonym for evolution but rather Darwin's explanation of evolution by natural selection.

3. Because of the confusion in separating the facts of evolution, the theories of evolution, and the hypotheses of evolution.

Regardless of the misunderstandings that have arisen the basic principle of evolution is accepted today as being as well established as the laws of gravitation and as usable in predicting events.

It has made possible some unity in the complex array of data accumulated through 200 years of intensive biological observation and

experimentation on the part of many individuals in many different countries. This synthesis of many isolated observations enabled scientists to formulate a reasonably logical pattern of nature and see not a world of chance and chaos but a world of design.

VI. *Facts, Theories and Hypothesis of Evolution*

A. Facts of Evolution

Darwin states in clear terms the facts from which he derived his theory of evolution. These were:

1. Overproduction.
2. Struggle for existence.
3. Variation.
4. Survival of the fittest.
5. Inheritance.

Of these he wrote—"Innumerable well-observed facts were stored in the minds of naturalists ready to take their proper place as soon as any theory which would receive them was sufficiently explained." He gives credit to many different individuals for having contributed to the discovery of these facts. From these facts, however, which he verified during many years of observation and study, he formulated his theory of "Origin of Species through Natural Selection."

B. Theories of Evolution

1. Buffon—1747—Origin of Species through Degeneration.
2. Lamarck—1809—Evolution through Environmentally Produced Modification.
3. Saint-Hillaire—1828—Conditions of Life Cause Change.
4. Von Buch—1836—Varieties Slowly Become Changed into Permanent Species.
5. Patrick Matthews—1831—Saw clearly the principle of natural selection.
6. Darwin—Natural Selection.
7. De Vries—Mutation.
8. Anderson—Introgressive Hybridization.

C. Hypothesis of Evolution

All organisms are interrelated and have arisen through common ancestry.

VII. *Conclusion*

Darwin, his contemporaries, and later workers gave concepts of "macro-evolution" using paleontology, embryology, morphology, and biogeography for evidence to support the concepts. None of them, however, gave information about the *arrival* of species but rather their *survival* after having arrived. From their accumulated observations we were able to get a picture of the principal historical steps and events of evolutionary processes.

Present day emphasis is placed on "micro-evolution" or evolution taking place in a shorter time, within smaller groups of organisms and lower systematic categories. By this method we can get exact scientific evidence regarding the mechanism of evolution. Here the main phenomenon is geographical variability and speciation.

DARWIN'S ANATOMY OF HUMAN NATURE

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Darwin was the dogged naturalist. Indeed, his own faithful formula was, "It's dogged does it." He devoted eight years to studying the poor and graceless barnacle, and wrote three exhaustive but little known books about that humble creature. With equal devotion he studied coral reefs, volcanic islands, insectivorous plants, vegetable molds, and many other particulars of natural history. The pedigree of liberal and stubborn labor permeates his works. In all this painstaking research his fundamental quest was for an explanation of variations and transformations. His theories of natural selection, of sexual selection, of gemmules and the rest all aimed to bring the observable processes of change and variation before the court of rigorous inquiry.

This dogged pursuit of processes was unknown before Darwin's time. The ancient Greeks discussed biological change, but as the emergence of an inherent nature. They believed it is simply the nature of acorns to become oaks. This nature involves an inner principle, an instinctive function that leads every thing to realize its own essence. Darwin did not seek inner principles or ontogenetic immanences. He sought overt agencies and mechanisms that produce phylogenetic change. Nor did he think in terms of metaphysical essences. He was not concerned with the universal nature of barnacleness. He was simply concerned with the varieties of barnacles. But he did not want a mere description of these varieties, nor a simple calendar of the sequence from fish to frogs. He sought the casual processes that led to variations, and that led fish to become frogs. This strenuously empirical quest for natural processes split the atom of all our thinking.

When Darwin considered man and culture he proposed the heathenish idea that our forefathers were aboriginal beasts. Here, however, he was not dogged enough. His principal contribution to anthropology, *The Descent of Man*, is a work flecked with fascinating tidbits, such as the South American parrot that was the only surviving creature that could speak a word of the language of an extinct tribe. But on the whole, this is an amorphous and inconclusive book. It falters in its concern for processes and in its empiricism.

The principal section of this book is a mixture of Huxley and Hume: partly an exhibit of man's place in nature, and partly a treatise on human nature. Huxley showed that man is like the primates in form and embryonic development. But Huxley did not show how man evolved. Although he speaks of natural selection, he does not show with any detail how natural selection produced the human type. Darwin fails here too, but he is aware of his failure. Therefore, *The Descent of Man* develops a theory of sexual selection to account at least for the varieties of mankind. The long discussion

of sexual selection is really another book, however, and it is not significantly related to the processes of human evolution.

Darwin's failure to analyze the processes of our own descent has many sources. One is our anthropocentric myopia. We demand more details about our human evolution than about the evolution of fishes and frogs. Moreover, Darwin had sufficient data from all the different species to develop a general theory of evolution, but he did not have sufficient data on the human species to apply that theory to man. Still another source is that man is more complex than the other species, for with the advent of man evolution itself evolved. The rest of nature may change by the crude and laborious processes of adaptive radiation and the transmission of genes and chromosomes, but man changes primarily by the processes of cultural innovation and the transmission of knowledge through speech and symbols. Darwin sensed something of this difference, but his stars held him to a different course. We cannot hold him accountable for obstacles like these, but a less obvious source of his failure was his treatment of human nature, which was too much like Hume, and also too little.

Hume was a dour empiricist; but an epistemological one, a theorizer rather than a practitioner. He held that mental science is basic to the study of man, and in this science Hume's own investigations consisted mainly of speculation and introspection. He surveyed our cognitive powers and passions—reason and experience, love and hate, pity and malice—and concluded that a prime attribute of man is his moral sense. This idea of a moral sense approaches the more recent notion of a force that holds society together, the consciousness of kind. Darwin, the dogged practitioner of science, followed Hume in each of these steps.

Darwin translated Hume's cognitive powers and passions into mental powers and moral faculties. He added that they have a natural history in zoological evolution. Monkeys and apes have them, and thus they give a further proof that human nature is related to the rest of nature. This put Darwin well ahead of many scholars of today: culture and human ways of life are not uniquely human; the seeds are planted in prehuman soil.

Nevertheless, Darwin's survey of our mental powers and moral faculties remains Greek in outlook. These psychological characteristics, he obviously thought, are properties of human nature, just as the Greeks thought they were predicates or attributes of man's very essence. For the Greeks this was quite in keeping with their view of how acorns become oak trees; but for Darwin, the empirical investigator of processes, this was incongruous and beside the mark.

Powers and faculties are not the wellsprings of push that cause our conduct. They are merely names that describe our conduct. When we see dogs chasing their tails, it is superfluous to think they have an instinct for chasing. When a man falls in love, it is redundant to say he has an amative faculty. In fact, whenever we explain behavior as the expression of an incarnate nature, we make no explanation at all. When we maintain that man is by nature a social animal,

we only say that he behaves socially. When we say that culture is an expression of human nature, we simply say that people behave culturally. We must strike these reified concepts from our descriptions, and brandish Occam's razor like a broadsword, for these powers and faculties are labels that can stifle our research into the processes of behavioral evolution.

When we analyze our conduct into inherent causes, we find no causes, and we renounce all further analysis. When we hold our conduct to be an expression of our human nature, we lower an iron curtain on further inquiry. When we say that dogs chase their tails because of their instincts or their canine nature, we are not only redundant but we leave nothing more to say. We have given an irreducible answer, for nature and instincts are themselves uncaused. They belong to the same clan of concepts as demiurges and spontaneous origins. They are tautological postulates and not phenomena; dicta and not data. And when Darwin adds that mental powers and moral faculties have evolved, he only says that conduct has changed.

Yet he fails to analyze the process of this change, because he regards our faculties and powers as things rather than events. Things are dense, discrete and static, while processes and events are flowing and continuous. When we consider acorns and oaks as things, we can ask, "At what point does an acorn become an oak? Where does one leave off and the other begin? Must the sprouts and shoots be two feet long or three?" We can ask, but cannot answer. Thus it is quixotic and perverse to proceed from things to processes. It is much more feasible to go the other way around, from processes to things. Indeed, we can look at oaks and acorns as events themselves, and think of them as ten o'clock and noon, as nominal mileposts in the flow of phenomena. We do not think the time of day is a bit of stuff or matter; similarity, we can think of acorns as events, as observed points that mark a general process. We can think of change before we think of the things that change. This, in fact, will shun the perils of reification and kindle the study of processes. Thus Darwin should have analyzed the changes in behavior more, and the origins of instincts less.

Hume and Darwin were twin anatomists of human nature. They both regarded man as a mundane creature. They both placed human reason among the natural forces, and removed it from the high office that it held under the Greeks. They both took inventory of our powers and passions. But Darwin was dogged while Hume was skeptic.

Hume made fewer assumptions, for he regarded all metaphysical entities with horror. Thus he banished all ideas of substance and causation from objective inquiry. And he even dissolved human nature itself. It is nothing but a bundle of unrelated perceptions in our minds. Here, however, he made a whopping assumption. The skeptic, trying to give philosophy the footing of a science, pulled the carpet out from under both.

Hume may well prefer percepts to concepts, but he cannot assume that percepts are unrelated to each other. We are not a bundle of unrelated perceptions. It is meaningless, no doubt, to discuss the true relations among things-in-themselves that are beyond our ex-

perience; but is is equally meaningless to say there are no relations at all. For meaning is a function of relations; and percepts are only meaningful in relation to each other. An event, like an eclipse of the sun, has meaning only in relation to some other event, such as a decree from the gods or the movement of the earth and moon. Thus we also get meaning in language through semantic and syntactic relations, and meaning in culture through the relations of customs to one another. We cannot reject relationships and retain science. Nor can we dissolve ourselves into atomistic percepts, and still precipitate the proper study of mankind. We must study relationships in order to explain those variations and transformations that Darwin pursued so doggedly. And he found highly meaningful relations, in nature and human nature.

DARWIN'S EFFECT ON PALEONTOLOGY

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Paleontology before Darwin

The era previous to the publication of the *Origin of Species* was active paleontologically, primarily in the field of fossil identification. There was little or no emphasis on genetic relationships.

Fossils were known, collected, and used before Darwin's theory came into vogue. They were primarily objects of scientific curiosity, but at the turn of the 19th Century, one of the first applications of the principle of faunal succession was made by William Smith in separating some of the rock layers of England on the basis of fossil content.

Cuvier, in the early 19th Century, showed conclusively that fossil vertebrates in the Tertiary of the Paris Basin were similar anatomically to modern vertebrates. He noted, furthermore, that they appeared to have a vertical distribution in which succeeding rock layers contained different fossils. He imagined each distinct group in each of the layers was created after those in the next lower layer had been destroyed by great calamities. His theory later became known as *catastrophism*. This theory of evolution was based largely on paleontologic evidence.

This same era of study produced the works of many famous men in the biological and paleontological world; among them are: Lamarck, D'Orbigny, Hall, Conrad, and Lyell.

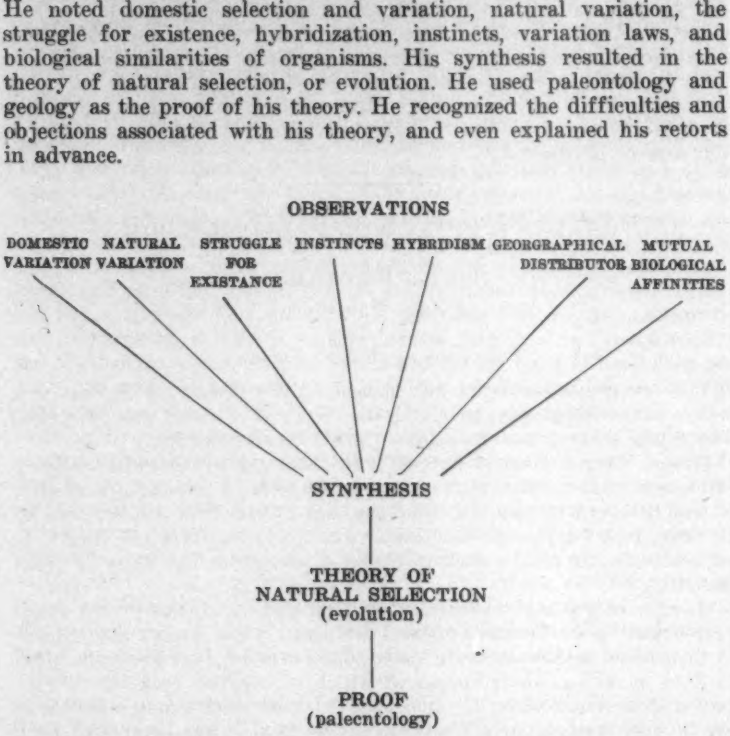
Darwin's Paleontology

It should be clearly understood that Darwin was principally a biologist and not a geologist or paleontologist. It is true that his earlier years were devoted in part to geology, but most of his later life was devoted to biology. For instance, of his 89 publications, 4 are about original paleontology, and 3 of these are about barnacles.

His observations about contemporary paleontology, however, are

very numerous and careful. He seems to have had insight in determining the true meanings and intent of others' work. His early paleontologic decisions were based on carefully selected works of his contemporaries, and it was not until later than he used his own synthesis of paleontology in connection with his theory.

Darwin's theory was based primarily upon biological observations. He noted domestic selection and variation, natural variation, the struggle for existence, hybridization, instincts, variation laws, and biological similarities of organisms. His synthesis resulted in the theory of natural selection, or evolution. He used paleontology and geology as the proof of his theory. He recognized the difficulties and objections associated with his theory, and even explained his retorts in advance.



Darwin recognized the fact that the geologic and paleontologic record was incomplete, and that while paleontology did not offer unquestioned proof of the theory, it was at least compatible with it.

Paleontology after Darwin

The theory was received with rejoicing in the paleontological fraternity because here at last was a rational explanation for the wide variety of fossils and for their vertical and geographical distribution.

In reading the paleontologic literature of the period immediately following the publication of the *Origin*, one quickly realizes that the *theory* had been carefully and subtlety eased over into the proof stage; evolution became a proof and was used as the mechanism to explain paleontological diversity. It was this same paleontologic

diversity which Drawin had tried to use as a proof for evolution, or for the mechanism of evolution.

Elaborate schemes of classifications arose which showed the relationships between species, genera, and other taxonomic categories. These were based primarily upon observation, but the influence of genetic association, either real or supposed, was very great, and in some cases the prime factor was evolution.

Fossils were united in vertical sequences, or phylogenetic trees, to show the supposed origin of one form in relation to others. Species were related by way of a common ancestor, as were genera and other taxonomic categories. The "common ancestor" became a fetish, and usually was labelled "hypothetical." Aberrant groups were recognized and speculation ran high about the mechanism of extinction.

Trends, or directional changes, were then recognized. Trends of getting larger, smaller, fatter, thinner, longer, shorter, more plates, less plates, and a host of other lineages were constructed once groups could be related vertically.

Paleontology today

In the past 20-30 years, great changes have come about in the philosophical use of the theory of evolution in connection with paleontology. As more and more paleontologic exploration and explanations accumulate, the awareness of the unknown increases even more. Paleontologists today realize that the unanswered problems and objections which Darwin recorded are even greater than he indicated; the imperfection of the record is much greater than he implied.

Modern paleontology suggests that the number of organisms preserved as fossils is minute when compared with the total number of organisms which must have lived. Knowing this proportion, the missing links would seem to far outnumber the [known] links.

A very cursory glance at the total volume of sedimentary rocks *exposed* at the surface of the earth indicates that it is very small when compared with the total amount of sedimentary rocks which are known to exist. Hence, our knowledge of paleontology to date is based on a very small part of the minute part of the total organisms which once must have lived. Darwin knew this, but the *"Origin"* does not seem to emphasize its magnitude nor significance.

Modern paleontology, employing statistical techniques, is revolutionizing the traditional classification. Entire new *phyla* have been created from organisms which were once part of a trend or were aberrant groups. Species are shown to probably encompass larger groups of varieties than once thought, and species and genera have been destroyed by showing that they are parts of a larger organism or juvenile forms of other species.

Orthogenesis, the idea of "internal, teleological, driving and directional forces from within" was based upon apparent trends. This idea is now largely discounted and has been replaced in part by *explosive evolution* which seems to explain much better the great and rapid diversification of fossils.

The validity of other specific trends has also been questioned and

some are now held invalid. Since individual organisms vary in an almost infinite number of ways from other organisms, and each individual organism has progeny which are different from it, a trend would require a "chance" variation of many factors in a single direction for many generations.

Many of the early identified trends were made when the knowledge of genetics was not very great. As an example, genes control the length of each bone in a leg, the thickness of each bone in a leg; genes control each muscle attachment, each bone in a foot or hand, skin, blood vessels, and so on. These would all have to change simultaneously and directionally over a long period of time and through a great number of generations to produce a trend as it is commonly thought of in traditional paleontology. The added disadvantage of an extremely incomplete record would also have to be recognized!

Modern paleontology is based in part on hypotheses which have been derived primarily from observations of fossils and geology. Proofs within paleontology are rare because of the nature of the geologic record and because of the time element involved in paleontology. It seems unwise to use paleontological hypotheses as proofs of another hypothesis when the nature of the material is considered.

In a sense, then, Darwin's theory did a disservice to paleontology in that it was taken as a fact by others and used prematurely in paleontology. Had paleontology been used and kept at the observation level, much of the present undoing of traditional paleontology would not have to be done.

On the other hand, if we put paleontology in the observation category, the only proof available would be the mechanism of significant genetic changes, which is not yet known.

CYTOGENETICS AND EVOLUTION

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It was sometime after the publication of Darwin's work and the development of his theory before the theoretical basis of modern-day genetics was developed. An understanding of the physical basis for heredity came still later. In fact, there was an approximate 60-year interval between these two events. During this interim, experimental evidence was hampered by the lack of necessary tools and knowledge. In the last 40 years tremendous strides have been made, advancing our knowledge in the field of experimental genetics. One of the fundamental questions—How is evolution accomplished and what is the mechanism by which it is accomplished?—remains unresolved. What evidence then does modern-day experimental genetics and cytogenetics provide?

Early in the study of genetics mutations were observed. In fact, mutations provide the best means of studying the genetics units or genes. It is the study of these genetic variations (or mutations) which enable us to understand the normal gene or hereditary unit. Early proponents of Darwin's theory seized upon mutations as providing the primary mechanism for the variation necessary in the origin of species. Here was a sudden and dramatic change in hereditary charactertistics which would provide a new individual. As investigations continued, however, certain facts became evident. Individual mutations were not sufficient to account for very large morphological changes and, indeed, those which produce the greatest change result from the loss of some function or structure—the so-called "loss mutations." Further investigation revealed another important fact; namely, that mutations are recurrent. This is of primary importance because it indicates there is a limit to the number of mutations. From a philosophical viewpoint, mutations may be considered as part of the natural, overall expression of a species. All that we may do by experimental means is to speed up the frequency with which these naturally-occurring mutations appear. This, of course, has the effect of increasing the inherent variation, but it does so through an increase in velocity rather than parameter. Experimental genetics has today powerful agents—mutagenic agents—which are capable of greatly accelerating the mutation frequency and the data obtained from such experimentation has shown clearly that it is the frequency of these recurring mutations which is affected, rather than the production of new mutations themselves. It has been argued that by increasing the frequency it becomes probable that more of these mutations may be segregated in a single individual and that this would provide the necessary mechanism for evolution. This is undoubtedly true to some extent, but it would only seem to provide the mechanism for a greater variation within a particular species gene pool. A particular species with a high mutation frequency would undoubtedly represent a particular species with a great deal of variation, but it still does not

provide the mechanism for a very sudden and drastic change in an individual.

If mutations do not provide the mechanism for major evolutionary change, what does? Have any evidences for evolutionary change been produced experimentally? The answer is yes. By the manipulation of larger genetic units than individual genes, it is possible to produce drastically new individuals. This can be accomplished either by manipulating whole sets of chromosomes or by manipulating individual or parts of individual chromosomes. These are not mutations in the gene-mutation concept, but are none-the-less hereditary and will be perpetuated. By manipulating entire sets of chromosomes several entirely new types of plants have been produced and the development of several existing species have been duplicated.

The manipulation of individual chromosomes or parts of chromosomes represents a drastic experiment and, as with most experiments, results in a large per cent of failure. There is, however, some evidence that this may provide one of the mechanisms for producing sudden and hereditary changes. The study of induced changes in the chromosome arrangement of organisms is one of the newest phases of cytogenetics and may provide answers to some of the major steps in evolution. The following table is a summary of experimental evidence on the relative expression of radiation-induced gene mutations and chromosome aberrations.

RELATIVE FREQUENCY OF RADIATION-INDUCED GENE MUTATIONS AND OF CHROMOSOME ABERRATIONS

Type	1st Generation	Total
Gross, Physical and Mental Defects (gene mutations)	1	10
Still Births and Childhood Deaths (gene mutations + chromosome aberrations)	2.5	38
Embryonic and Neonatal Deaths (chromosome aberrations)	5.0	87

After a given dose of high energy irradiation those groups of effects which are considered primarily as the expression of chromosome aberrations comprise the largest effect. Through a series of breakage-reunion-breakage phenomena between sister chromatids there is a continuous redistribution of genes. The effect of such gene imbalance is poorly understood, however, the drastic visible 'mutations' and embryonic deaths are readily observed. Such chromosome instability will persist through several generations and will continue to express a profound effect on entire embryonic segments until either eliminated by embryonic death or until a stabilization by "healing" of

the chromosome aberration. The modification of an entire embryonic segment or organ by such a process can thus ensue.

This latter process has been demonstrated, but our experimental knowledge is meager. It should be kept in mind that the 'failures' of these drastic experiments will be hidden from view and will be expressed as a reduction in fertility of a species (smaller litter size, etc.). Such process would not require a continuous series of small step changes over a long period of time to bring about a major modification in an organism. The imagination of a great many people has been strained to believe that major evolutionary changes could result from accumulation of many seemingly unrelated gene mutations.

ERRATA

The following corrections should be made in the June 1959 (No. 3.) issue.

Page 88 Footnote 2 should read *Beaufort, North Carolina.*

Page 89 Lines 9 and 10 should read "the time interval between the two *sampling* series."

Page 89 From bottom line 4, "criteria *mature* at different times."

Page 103 Line 20, should read, "Cross transmission of parasites between animal species does occur."